Towards a Unified Approach to Evaluating Regional Earthquake Hazard and Risk in the Cordilleran Region - Including Relevant Efforts Along the Wasatch Front

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Investigations Undertaken

The above research project provides funding for investigations of ground motion along the Wasatch fault, Utah, using continuous GPS monitoring and fault stress modeling incorporating new Holocene slip rates, contemporary seismicity and GPS-determined deformation rates. Support includes the operation of the University of Utah's 5 station GPS Wasatch fault array, GPS data processing and data archiving to a publicly accessible web site.

Results (October 1, 1997 to September 30, 1998)

General Accomplishments--Under this project the University of Utah received support to assess earthquake hazard on the Wasatch Front, Utah using continous GPS measurements and incorporating models of normal fault behavior. Because of reduced funding from our proposed project, tasks were reduced to three main research components: 1) installation of two continuous recording GPS sites on the Wasatch Front, Utah, bringing the total to five continuous recording GPS sites for the purposes of monitoring ground motion that may be associated with the seismically dormant Wasatch fault, 2) operation of the University of Utah's 5 station permanent GPS array, and 3) research on understanding time-varying behavior of ground deformation of the Wasatch normal fault incorporating GPS results, the paleoseismic record and fault stress interactions. Specific efforts included:

- The installation of a new GPS station at Lake Mountain, located in the hangingwall of the Wasatch fault and extends the array coverage south to the Provo segment.

- The installation of a new GPS station at east Ogden, Utah, in the footwall of the Wasatch fault and extends the array coverage north to the Weber segment.

- Operating five GPS stations to provide the multiple baseline crossings of the Wasatch fault for monitoring ground deformation (see Fig. 1).

- Continued design of permanent GPS stations and digital telemetry to withstand rugged, mountainous terrain in cold weather climate.

- Installation of a UPS and extended the memory of the UltraSparc recording computer to 256 MB with an additional 9 GB of disk storage.

- Initiating incorporation of data from three of the 18-station Northern Basin and Range continuous GPS network operated by CalTech (Brian Wernicke) and Harvard Smithsonian (Jim Davis) into our processing scheme. Although their data were not availiable on line we were able to co-process data from both networks that will be continued this year with near real-time processing.

- Presented invited and contributed papers on our research at four scientific meetings: 1) the 1998 Annual Meetings of the Seismological Society of American, Boulder, Colorado, and 2) at the 1998 Fall Meetings of the American Geophysical Union, 2) at the USGS sponsored probabilistic volcano hazards meeting in Menlo Park California, and 4) at the SCEC science workshop on fault stress interaction.

GPS Array Operation – Our GPS sites are designed to operate in high mountainous, cold weather conditions planned for unattended operation for several months at a time. The instrumentation includes photo voltaic power (except for Lake Mt.) and digital spread-spectrum radios for communications between the sites and the University of Utah recording laboratory. Choke ring antennas are attached to Invar rods set in four to six foot long drilled boreholes drilled into bedrock. All stations are equipped with Trimble Ssi dual-frequency GPS receivers that were made acquired at no cost to the project by a grant to the University of Utah from the National Science Foundation. Each receiver and antenna is valued at $22,000. Spread spectrum digital radio receivers at the University of Utah campus receive the GPS data which and are connected by a special radio line to the University of Utah recording laboratory linking to a Sun UltraSparc 170e (acquired by the University of Utah at no cost to the project.) Data are sampled at 30-second rates..

Data Processing--Daily processing of the Wasatch Front GPS network uses the Bernese Engine GPS processing software. Included with the processing with the five Wasatch permanent GPS stations are seven International GPS Service stations in North America. These stations provide essential reference frame constraints and baseline ties to stable North America. By constraining rather than fixing the coordinates and velocities at the IGS sites to the ITRF96 frame, solutions SINEX files can rigorously be combined with solutions for regional stations determined by other institutions who use other processing software.

Problems Encountered -- The East Ogden GPS site was vandalized shortly after installation in late fall 1997 when someone tampered with the solar panel mounting and destroying the

acrylic dome that is used for protecting the GPS antenna. The antenna and the solar panels were undamaged. An amplifier in the GPS antenna at the Surveyor-1 site in the center of the Salt Lake valley failed in late summer and was repaired under warranty. The Red Butte Canyon (RBUT) and Antelope Island (NAIU) sites experienced no problems in the last year.

Research Results -- The first attempt to combine the Northern Basin and Range results of Cal Tech/Harvard Smithsonian with the University of Utah Wasatch results was presented at the 1998 SSA meeting (Bennett et al., 1998). The first results using up to 1.5 years of Basin and Range data and 4 to 12 months of Wasatch Front data show successful integration at the 1 mm/year level. They suggest strain concentration along the Wasatch fault (44± 22 nanostrain/year) which is several times the regional extension rate inferred from the Holocene earthquake record but similar to that determined by our 1992-1995 campaign GPS surveys (Martinez, et al., 1998). When permanent station data from other regional Basin and Range permanent stations become available, we will include them as well in our automated processing.

Our analysis of the earthquake potential of the Wasatch fault has focussed on the failure stress analysis of normal faulting earthquakes. Coulomb failure-stress by elastic boundary-element modeling was used to model two largest historic Intermountain Seismic Belt earthquakes, 1) the 1959 Hebgen Lake (Ms 7.5), Montana, and 2) the 1983 Borah Peak (Ms 7.3), Idaho. These models provide important constraints on fault geometry and aftershock distributions pertinent to the occurrence of large earthquakes on the Wasatch fault. The analysis also reveals that aftershocks are concentrated in quadrants of increased stress loading on appropriately aligned faults that may extend up to 20 years or longer after the mainshock.

The modeling corroborates the application of the method to the paleoearthquakes on the Wasatch fault, which is located within the same extensional stress regime as the Hebgen Lake and the Borah Peak ruptures, but has been seismically quiescent in historic time. Modeling of ages and fault displacements from sixteen trench sites along the Wasatch fault were used to develop space-time scenarios of 17 scarp-forming, paleoearthquakes, M7+, in the past 5,600 years, including as many as eight, multiple-segment ruptures. Using the paleoearthquake data, the occurrence rate of large, Mw > 6.6 earthquakes on the Wasatch fault is about four times higher than that predicted by the historic seismicity of the Wasatch fault, but lower than that predicted by the 1960-1995 geodetically determined strain rate of the Wasatch Front, Utah. This suggests that aseismic moment due to fault creep or interevent fault-loading may be an important mechanisms that affect estimates of earthquake hazard.

Non-Technical Summary

Under this research project, the University of Utah conducts research on time-varying behavior of the Wasatch fault by precise measurements of ground motion using continuous-recording GPS (Global Positioning Systems) satellite receivers. The sites are mounted in bedrock and transmit data to the University of Utah via radio links for recording and processing. The project is a follow-up project to confirm measurements from 1992-1995 of temporarily deployed GPS receivers along the Wasatch fault that revealed unexpectedly high

deformation rates of 2 to 3 times faster loading of the fault than deduced from geologic determinations. The new GPS network incorporates data from a collaborative network of GPS stations across western Utah and northern Nevada. Data from the our network are provided the local surveying community for high accuracy reference ties.

Papers Published In National Journals

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Presentations At National Meetings Related To Project

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Smith, R.B., W. L. Chang, C. M. Meertens and R. Palmer, 1997, Paradigm and Paradox: Integrative earthquake risk assessment of dormant faults in the Intermountain region with models of the driving mechanism and fault stress interaction, Special USGS Workshop On Utilization of Geological Data in Seismic-Hazard Mapping, July 30-31, Salt Lake City, p. 44.

Availability of Data

All Wasatch Front campaign and continuous GPS data are archived in Rinex format the UNAVCO (University NAVSTAR consortium) data management center, Boulder, Colorado at unavco.ucar.edu/data. Hourly data from the RBUT and SURV1 stations are provided to the National Geodetic Survey and contribute to the NGS CORS on-line network which are accessible by ftp at ftp://cors.ngs.noaa.gov/coord. This component of our research project provides the local surveying community with local base stations. As soon as a reliable automated processing scheme is completed all of our data along with the Northern Basin Range array data will be availiable on-line at.

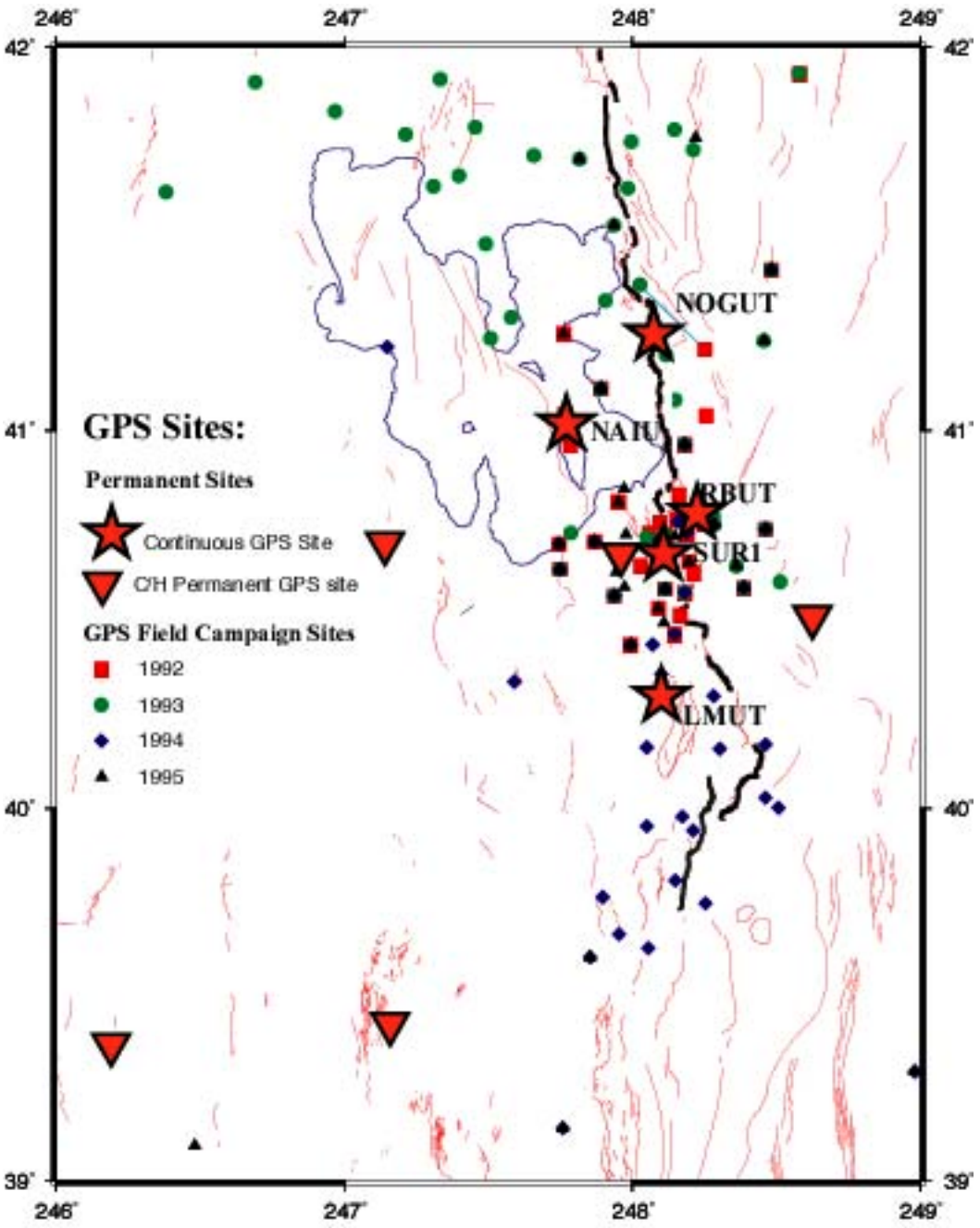

Figure 1. Map of University of Utah Wasatch Front GPS sites, including permanent stations and 1992-1995 survey points.